KERNALL

An Undescribed Species of Tubifex from Illinois

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AN UNDESCRIBED SPECIES OF TUBIFEX FROM ILLINOIS

BY

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THESIS

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JUNE 6, 1914. 190

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

MORRIS JOHNSON KERNALL

ENTITLED AN UNDESCRIBED SPECIES OF TUBIFEX FROM ILLINOIS

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF ARTS

Frank Smith
In Charge of Major Work

Henry B Ward
Head of Department

Recommendation concurred in:

Committee
on
Final Examination

AN UNDESCRIBED SPECIES OF TUBIFEX FROM ILLINOIS.

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AN UNDESCRIBED SPECIES OF TUBIFEX FROM ILLINOIS.

In September 1913, the writer began a study of the Tubificidae in a small creek at Urbana, Illinois, locally known as "The Boneyard". The work was done as a part of the requirements for the degree of Master of Arts at the University of Illinois.

The previous work on Illinois Tubificidae has been limited to that done by Professor Frank Smith of the University of Illinois, under whose direction the work here described was carried on. In 1900, Professor Smith listed Tubifex rivulorum Lamarck and Limnodrilus claparedianus Ratzel as occurring at Urbana and Havana, Illinois, and described Rhizodrilus lacteus, a new genus and new species, and Embolocephalus multisetosus, also a new species. The last two were found at Havana, Illinois, where they were abundant.

Tubifex fissidens n. sp.

DEFINITION. Color pale reddish, due to blood. Length 28-66 mm. Transverse diameter at VII .35 mm.; at XI a little over 1 mm. Dorso-ventral diameter at XI .9 mm. Somites 45-106. Prostomium narrowly "zygolobic", or narrowed with a somewhat blunt point. Somites I and II biannulate; III and IV triannulate. Ventral setae all sigmoid and bifid, in two rows of bundles; 1-5 setae per bundle. Dorsal setae of two kinds: (1) Sigmoid and bifid, with 0-5 accessory teeth and the main (outer) teeth often notched at the tips; and (2) pilose, capilliform setae. Both kinds usually occur in the same bundle. Capilliform setae 0-2 per bundle, the longest equal to about half the greatest clitellar diameter of the worm. Ventral setae in XI shorter than those in adjoining somites. Brain a little wider than long, emarginate anteriorly and poster-

iorly. Large, paired, hearts in VIII. Dorsal vessel covered with chloragogue cells. Nephridia usually 2 per somite, but absent in I-VI and IX-XI inclusive, in sexually mature specimens. Spermaries paired, in X. Sperm sacs in IX are anterior invaginations of septum IX/X, sometimes extending anteriorly into VIII. Sperm ducts much coiled, 5-6 mm. long, in XI XII and XIII, with spermiducal funnels in X. Atria in XI, large, club-shaped. Spermiducal glands large, sessile, devoid of lumen. Penes eversible, without chitinous sheath. Spermathecae paired, large, each with an ampulla and long narrow duct opening to exterior through a transverse pore in X, mesad of the ventral setae. Clitellum complete, X-XII inclusive. Ovaries in XI.

Tubifex fissidens is the only species of the genus that the writer has found in this vicinity. The worms are numerous and easily collected at all seasons of the year. In late summer and fall they are often seen in masses up to three or four inches in horizontal diameter, floating at the surface of the water, attached to decaying organic matter upon which they feed. At other times they live in the mud at the bottom.

The description is based upon a type specimen, and is supplemented where so indicated, by observations on paratypes. Sexually mature specimens are described, except where otherwise indicated.

EXTERNAL CHARACTERS.

COLOR. Tubifex fissidens is pale reddish. The color is due to the blood and is most pronounced in VIII and immediately posterior to the clitellum. The worm is somewhat iridescent when seen by reflected light.

LENGTH. Length when completely chloretoned, 70 mm.; when in 85 per cent alcohol, 53½ mm. Number of somites, 74. The posterior end to a length of 23 mm. is whitish, and the somites are relatively small, indicating recent regeneration. Paratypes are from 28 to 66 mm. long when partially chloretoned, with the somites varying in number from 45 to 106. There is no definite relation between the length and the number of somites. Thus one worm of 40 mm. had 104 somites, while another of 60 mm. had but 80. The most frequent length is 45 mm., occurring in approximately one sixth of the specimens. One factor influencing the length is the habitat. Those living on a sandy bottom are shorter than those living in the mud.

DIAMETER. The transverse diameter is .35 mm. at VIII, and 1 mm. at XI. The greatest transverse diameter observed in the paratypes was 1.2 mm. at XI. Dorso-ventral diameter at XI .95 mm.; at II .5 mm.

CLITELLUM. This includes nearly all of X$_{\wedge}^{\text{XI}}$and XII. In some paratypes it involves ½X-XII and in others ¼X-¾XII. The clitellar cells and epidermis have a combined thickness of .036 mm. immediately anterior to the male pores. Paratypes have many hyaline, granular bodies in the gland cells. These cells are rather closely set, but they were never observed to be in contact.

PROSTOMIUM. In the non-chloretoned, living paratypes, the prostomium is usually bluntly pointed, but in the chloretoned animals it is most frequently narrowly "zygolobic". Its form is not sufficiently definite and constant to be of much systematic value.

ANNULATION. Somite I is distinctly biannulate, the smaller,

caudal annulus being about one third as wide as the anterior. The annulation of somite II is similar to that in one, but is not as well marked. In addition to two annuli such as are found in I and II, somites III and IV have indications of a third annulus posterior to the large second annulus. Somite V is indistinctly annulated or is without annulation.

SETAE. All the setae are set in slight, papilla-like eminences. They are arranged in two dorsal and two ventral rows of bundles. One bundle of each row occurs in each somite except the first and last.

Ventral. These are all sigmoid and bifid (Pl. I, Figs. 11, 12). Five fully formed setae is the usual number per bundle in the pre-clitellar somites. In XIII-L two is the usual number per bundle. Posterior to L, there is only one seta in each ventral bundle. The longest ventral setae are in VI (.21 mm.) and in VIII (.25 mm.). The setae in the post-clitellar bundles do not exceed .16 mm. in length. Their average length is approximately . 13 mm. Posterior to L. .14 mm. is the greatest length observed in the type.

Dorsal. The dorsal setae consist of two kinds,- sigmoid and bifid, and capilliform. Bifid Setae. These usually number from three to five per bundle, from II to XIII inclusive. Two per bundle is the usual number in XIII-L. Posterior to L one per bundle is the almost unvarying number. The longest bifid dorsal setae are in V (.19 mm.) and in VI (.18 mm.). In the post-clitellar somites they seldom exceed .13 mm. The dorsal bifid setae have from one to five accessory teeth, except in the posterior portion, where the accessory teeth may be absent(Pl. I, Figs. 1-6,

and 9, 10). There is a marked tendency in the main (outer) teeth to divide at the tip (Pl. I, Figs. 1, 4). Capilliform Setae. There are never more than two mature capilliform setae per bundle. Two is the usual number in II-IX. In X-XLI at least one capilliform seta is present in each of three fourths of the bundles. The last one is in LVII. Those in the pre-clitellar bundles are the longest. One of .58 mm., - about one half the greatest clitellar diameter,- is in VII. Posterior to X .26 mm. is the most frequent length. The capilliform setae are densely pilose (Pl. I, Fig. 14).

The ventral setae in X are in two bundles of four each, and are normal in both size and form. The ventral setae in XI are normal in shape, but only about half as long (.08 mm.) as those in the two adjacent somites. They are mesad of the spermiducal pores. Normally each bundle has two setae, but occassionally paratypes had three setae in one of the bundles.

SPERMATHECAL PORES. These were not observed in the type. They are seen only with difficulty or not at all, except during certain stages of sexual maturity. They are paired slit-like openings placed transversely in X, directly ventrad of the dorsal setae and laterad of the ventral setae. They are from .08 to .09 mm. long. Their shape varies somewhat with the state of contraction of the animal. Each spermathecal pore has a double border. The inner one of these is the most prominent, and is of a lip-like character. The outer border is about a fifth wider than the inner one.

INTERNAL CHARACTERS.

NERVOUS SYSTEM. Brain. When seen from the side, the brain appears roughly club-shaped in outline, with the larger end

posteriad. The anterior extremity is in contact with the body wall (Pl. II, Fig. 3). Posteriorly and dorsally the brain is attached to the body wall by strands of a fibrillar, semi-transparent substance, apparently devoid of nuclei. In a paratype the length was .13 mm. and the greatest width .16 mm. The brain is emarginate. both anteriorly and posteriorly. The posterior emargination is the deeper. Paratypes show that the length of the brain is three to four times as great as the greatest dorso-ventral thickness. The remaining observations on the nervous system were made on paratypes.

Commissures. Two commissures are given off from the anterior part of the brain. Each of these extends ventrally and anteriorly alongside the esophagus. Proximally each has a dorso-ventral diameter about half as large as the greatest dorso-ventral thickness of the brain. The middle portion of each commissure is about two thirds as wide as the first ganglion, and takes only a very slight haematoxylin stain.

Ventral Nerve Cord. This lies close to the ventral body wall. It has a large ganglion in each somite. The first ganglion occurs in the anterior half of II. It is divided into two parts, the combined transverse diameter of which is equal to the greatest transverse diameter of the brain. Each of these two parts extends anteriorly and dorsally, uniting with the narrow, slightly staining portion of a commissure. The remaining ganglia are found slightly posterior to, or in line with, the setae of each somite. In the anterior part of the body the ganglia are nearly as wide as the widest portion of the brain. The ganglion in one paratype was .126 mm. in transverse diameter in V, and the nerve cord was .052 mm. in transverse diameter at septum V/VI. The ventral part of the

ventral nerve cord has cells with large, heavily staining nuclei. In the dorsal part no nuclei are visible. The number of nuclei diminishes gradually on either side of the ganglion. Midway between the ganglia no nuclei are visible in any part of the nerve cord, in ordinary preparations. Here it looks like the median, slightly staining part of the circum-oesophageal commissure.

ALIMENTARY CANAL. This includes the mouth, buccal cavity, pharynx, esophagus, intestine and anus. The posterior lip of the mouth is distinctly crenate. The buccal cavity is confined to I. Its walls are everted when the worm is chloretoned, and are then seen to be ciliated (Compare Stolc '85, p. 9 Translation). The pharynx is in II and III. It is a little more than three times as long as wide. In the paratypes the pharynx occupies two thirds of the space dorso-ventrally in II and III. It is attached to the body wall dorsally by retractor muscles extending as far posteriad as the setae of IV. Glandular cells envelop it completely. The esophagus is in IV and V. It is about four times as long as wide. A number of large glands are connected with it. The intestine begins in VI. It has the same diameter as the esophagus. Chloragogue cells invest it throughout its entire length. These are much larger than the cells covering the pharynx. In some of the living paratypes active cilia were observed in the posterior, regenerated part of the alimentary canal. Sectioned paratypes show the intestine to be ciliated internally throughout the greater part of its length at least.

COELOMIC CORPUSCLES. These are of three kinds: (1) pigmented, globular; (2) non-pigmented or but slightly pigmented and globular; and (3) elongated, colorless cells twice as long as those of (1).

CIRCULATION. The dorsal vessel is covered with chloragogue cells similar to, or identical with those which invest the intestine. It lies close to the dorsal surface of the intestine, except in IX, where it often looks like a small, lateral loop of the alimentary canal when the worm is not fully extended. Each chloragogue cell encloses many spherical bodies, and is separated from the others by an appreciable space. The visible contractions of the dorsal vessel begin a short distance anterior to the regenerated region, and proceed anteriorly. The remaining observations on the circulatory system are based on paratypes. The ventral vessel lies between the alimentary canal and the ventral nerve cord. Its diameter is constant in the living animal. Dorso-ventrally it is five times that of the nerve cord, measured at the septum. It divides into two parts in IX, and connects with the contractile hearts located in VIII, immediately posterior to, and ventrad of the dorsal seta bundle. The direction of blood flow here is posterior. The length of the heart is about .3 mm. Small blood vessels occur immediately anterior to the posterior septum in many somites. The blood is pale yellowish. It appears light red when seen in the hearts and larger blood vessels.

NEPHRIDIA. Somites VII and VIII each has one pair of nephridia. Nephridia are absent in IX, X, XI and XII in the type, but in the paratypes they are present in XII. They are present in XIII, and from there posteriorly, ceasing a few somites anterior to the evidently regenerated portion. The nephridial funnel extends through the anterior septum into the next somite anteriorly. The nephridial pore is in the same somite as the main body of the nephridium.

The remaining statements regarding nephridia are based upon a study of paratypes. In VII the bulk of each nephridium lies anterior to the hearts. The nephridia on the right side are frequently smaller than those on the left, in several somites of the same worm. This is especially apt to be true in VII and VIII. Nephriare not found in the recently regenerated somites. In the post-clitellar part of the worm, the nephridial tubes are closely appressed to the ventral vessel.

REPRODUCTIVE ORGANS. The spermaries are in X, attached to the anterior septum and near the ventral body wall (Pl. II, Figs. 1, 5). They are roughly elliptical in outline, .13 mm. long, and about .05 mm. in diameter. In the paratypes the spermary of one side is sometimes twice as large as the other. The length is usually twice the diameter, and sometimes reaches .25 mm. Each of the paired sperm ducts is confined normally to XI$\overset{\text{XII}}{\wedge}$and XIII (Pl. II, Fig. 1). Each terminates anteriorly in the spermiducal funnel and posteriorly in the penis (Pl. I, Fig. 15; Pl. II, Figs. 1, 5, 7). The two sperm funnels are apparently of the same size. They are .18 mm. wide, including a ciliary margin of .024 mm. on each side. Each is about .28 mm. long. A sperm duct dissected from one of the paratypes is 2.5 mm. long, though still much coiled and contorted. If completely uncoiled it would probably measure between five and six millimetres. Each of the two atria is club-shaped in outline as seen from the dorsal side, with the posterior end the wider. The anterior portion into which the penis is invaginated, is enlarged just beneath the integument. The atria push septum X/XI anteriorly a little. The length of each is about .74 mm. and the greatest diameter .16 mm. An atrium from a para-

type measured .5 mm. in length, and had a maximum dorso-ventral diameter of .3 mm. The spermiducal glands (Pl. I, Fig. 15; Pl. II Figs. 1, 5) are large and stain deeply. They are not stalked. In a paratype, a spermiducal gland with a length of .22 mm. had a maximum dorso-ventral thickness of .11 mm. The spermiducal gland is connected with the atrium by numerous thin-walled, elongated, non-staining cells. Each penis has a lumen continuous with that of the atrium. Upon retraction of the penis, its sides invaginate into the penis sheath, so that a cross section of this organ will often show the penis wall sectioned at two different levels (Pl. I, Fig. 15). The sperm cells are long (about .05 mm.) and slender, with a small, globular, head. They gather about the granular secretions of the cement glands, their posterior ends extending radially, only the heads being attached. A pair of sperm sacs are formed by anterior invaginations of septum IX/X, occupying most of IX. Normally they push septum VIII/IX anteriorly to a slight extent, but when under pressure they may extend half way into VIII through the sub-intestinal perforation of VIII/IX. A single sperm sac extends posteriorly,- in some paratypes as far as ½XV.

The paired ovaries are in XI, attached to septum X/XI (Pl. I, Fig. 15; Pl. II, Figs. 1, 5). The right ovary is .41 mm. long, and its greatest width is .18 mm. In one of the paratypes one of the ovaries was about .5 mm. long. The ova are large, spherical, and white. They extend posteriorly into XVII. They are plastic (Pl. II, Fig. 5) and may migrate from somite to somite. Thus in a paratype, one ovum was seen when under pressure, to travel from XIII to XVI, changing its shape while doing so, but finally assuming the same spherical form it had when first observed. The single

ovisac is limited to the dorsal side of the intestine. It arises as a posterior evagination of XI/XII.

The data for the spermathecae are derived exclusively from observations on paratypes. The spermathecal pores have been described previously. The size and shape of the spermathecae depend upon the muscular contractions of the animal at any given time, and also upon the state of sexual activity. They may be merely spherical bodies closely appressed to the ventral body wall, and without a distinct duct. At a later stage each spermatheca has a long, distinct duct and a globular ampulla shorter than the duct (Pl. I, Fig. 17). In many of the specimens examined the spermathecae could not be found, even though the animals showed considerable sexual development. The spermathecal ducts look much like the sperm ducts in the living specimen, but stain differently. In living paratypes the spermathecae often extended anteriorly into ½VIII. The measurements are as follows for a worm of small size, but with well developed spermathecae: Ampulla .33 mm. long, maximum diameter .25 mm.; lumen of duct near pore, .02 mm. In this specimen the spermathecae contracted spasmodically. The contractions did not occur at regular intervals. At times the proximal part of the duct was invaginated into the ampulla. In another paratype the single functioning spermatheca (Pl. II, Fig. 5) was 1.5 mm. long, and .3 mm. wide. In this case it extended posteriorly only, reaching ½XIII.

COCOONS. A number of cocoons were obtained from specimens collected March 21, 1914, and kept in shallow aquaria with a small amount of mud and a little water. They are broadly oval, with a projection at each end, which seldom exceeds .008 mm.

AFFINITIES. Pointner ('11, p. 636) gives the following generic characters for Tubifex: "Ein ausstülpbarer bzw. vorstülpbarer Penis vorhanden. Dorsale Hakenbörsten am Vorderkörper anders gestaltet als die ventralen. Haarborsten nur individuell fehlend." The sub-genus Tubifex is distinguished as follows: "Körperoberfläche nackt, ohne chitinöse (?) Hülse, ohne Hülsenpapillen. Samenleiter länger als das Atrium" (See also Michaelsen, 1909, pp. 34-35). Tubifex fissidens conforms to both of these characterizations. It approaches T. tubifex (rivulorum) Müll. more nearly than it does any other described form of the sub-genus Tubifex, on account of marked similarity in internal organization, especially in the sperm ducts, atria, penes, and spermathecae. There are however, several characters that separate the two. The spermiducal gland in T. tubifex is described as narrow (Michaelsen '09, p. 37; '00, p. 48), while in the species here described it is broad, surrounding the greater part of the atrium. Slides of T. rivulorum from Havana, Illinois, in the collection of Professor Smith, show unquestionably that the brain is longer than wide (Average maximum length .14 mm., average maximum width .09 mm.). In paratypes of T. fissidens the length of the brain is invariably exceeded by the width (Average measurements: Length .13 mm.; width .18 mm.). No posterior, median, projection from the brain is present, as described by Beddard ('95, p. 244) and figured by Vejdovsky ('84, Taf. VIII, Fig. 1) for T. tubifex.

The external characters separating the two species are even more pronounced. Michaelsen gives 40 mm. as the maximum length for T. tubifex, and Smith finds 50 mm. the maximum for the Illinois specimens ('00, p. 444). The maximum length of T. fissidens is

66 mm. According to Smith, the maximum number of somites in the Illinois specimens of T. rivulorum is 60, while in the present species it is 107. T. fissidens has not been observed to build tubes.

The setal differences are perhaps the most evident. The ventral setae are never pectinate, tho pectinate setae sometimes occur in specimens of T. rivulorum from Havana, Illinois. The latter also lack ventral setae in XI (Smith '00, p.444), while in T. fissidens the ventral setae are always present in XI. The main teeth of the dorsal bifid setae of T. tubifex are described and figured as "gleichzinkig." (See Michaelsen '00, p. 48; '09, p. 37 and Fig. 73). There is considerable variation in T. fissidens, the lower tooth of the bifid dorsal setae being in some cases even larger and longer than the upper tooth (Pl. 1, Fig. 9), but normally the upper tooth is larger and longer than the lower (Plate I, Figs. 2, 5, 6, 10). The angle formed by the main teeth of the dorsal bifid setae is less than in T. tubifex, and the tips of the main teeth in T. fissidens are blunt in comparison with those in T. tubifex, and tend strongly to divide (Pl. I, Figs. 1, 4). In T. tubifex there is no indication of such division whatever. T. tubifex has only bifid dorsal setae, without any accessory teeth on the middle and posterior parts of the body (Michaelsen '00, p. 48). Vejdovsky ('84, p. 46) says: "Vom 16 Segmente an bis zum hinteren Körperende sind nur gegabelte Börsten vorhanden." In T. fissidens, setae with from one to four accessory teeth are frequent posterior to XVI (Pl. I, Figs. 2 , 3). Thus, one paratype with a total of 43 somites has dorsal bifid setae with three accessory teeth, in XXXV. Smith has shown that the dorsal capilli-

form setae extend further posteriad in the Havana, Illinois, specimens of T. rivulorum than in the European forms. In T. fissidens the capilliform setae extend even further posteriad and occur more regularly than they do in the specimens of T. rivulorum from Havana, Illinois, examined by me. Smith found four to five capilliform setae per bundle anterior to the clitellum, while in T. fissidens there are never more than two mature capilliform setae per bundle. The capilliform setae of T. fissidens are densely pilose, never smooth, as in T. tubifex.*

Of the species of the subgenus Tubifex having so-called "hairy" setae, T. ignota Stolc, and T. albicola are apparently the nearest to T. fissidens. T. ignota agrees with T. fissidens in that it does not have specially modified setae in X or XI. It differs, however, in the character of the dorsal bifid setae and in the arrangements of the projections on the capilliform setae. Stolc ('85, p. 75) says expressly that each capilliform seta in T. ignota has only two rows of projections while in T. fissidens the projections occur on the entire surface of the seta exposed above the cuticula. The atria and spermiducal glands of T. ignota are also different from those of T. fissidens. T. albicola has pilose capilliform setae, but it has the ventral setae in X specially modified, and it also differs from T. fissidens in its sperm ducts, atria, and spermiducal glands.

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* See tabular comparison on page 15.

COMPARISON OF TUBIFEX FISSIDENS WITH TUBIFEX TUBIFEX

	Maximum length	Brain	Prostate	Base of penis	Ventral Setae
T. fissidens	66 mm.	Wider than long; no median projection	Wide	Without glandular widening	Never pectinate
T. tubifex	40-50 mm.	Longer than wide; Median posterior projection	Narrow	With glandular widening	Sometimes pectinate

	DORSAL CAPILLIFORM SETAE			DORSAL BIFID SETAE			
				Main Teeth		Accessory Teeth	
	No. in bundle	Length	Surface	Angle	Tips	Max. No.	Character
T. fissidens	2	About ½ diam. of body	Pilose	20-25°	Rather blunt; often cleft	5	Never adnate
T. tubifex	4-5	Exceeds ½ diam. of body	Smooth	40-43°	Acute; never cleft	3 (?)	Often adnate

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EXPLANATION OF PLATES

Abbreviations

amp., ampulla
at. w., atrial wall
at., atrium
b. w., body wall
br., brain
h., heart
hyp., hypodermis
int., intestine
m. ls., muscle layers
n., nucleus
o., ovary
ov., ovum
pen. s., penial seta
p., penis
p. w., penis wall
sep., septum
s., seta
sp. th., spermatheca
sp. th. d., spermathecal duct
spy., spermary
sp. ph., spermatophore
sp. d., sperm duct
sp. d. f., spermiducal funnel
sp. d. gl., spermiducal gland
sp. d. gl. d., duct of spermiducal gland
sp. d. po., spermiducal pore

PLATE I

Figs. 1-6. Dorsal bifid setae.

Figs. 7-8. Dorsal bifid setae of Tubifex tubifex. From Michaelsen after Beddard.

Figs. 9-10. Dorsal bifid setae.

Figs. 11-12. Ventral setae.

Fig. 13. Scale for all figures of setae, except 7 and 8.

Fig. 14. Portion of dorsal capilliform setae.

Fig. 15. Frontal section.

Fig. 16. Scale for Fig. 15.

Fig. 17. Outline of spermatheca of paratype, as seen through the integument of the living animal.

Fig. 18. Scale for Fig. 17.

PLATE II

Fig. 1. A portion of type specimen, shown as a partially transparent object.

Fig. 2. Scale for Figs. 1 and 7.

Fig. 3. Lateral, sagittal section, showing commissure, and arrangement of nuclei in the brain.

Fig. 4. Scale for Fig. 3.

Fig. 5. Sagittal section, showing principal organs.

Fig. 6. Scale for Fig. 5.

Fig. 7. Spermiducal apparatus dissected from a paratype (Spermiducal gland not shown).

PLATE I

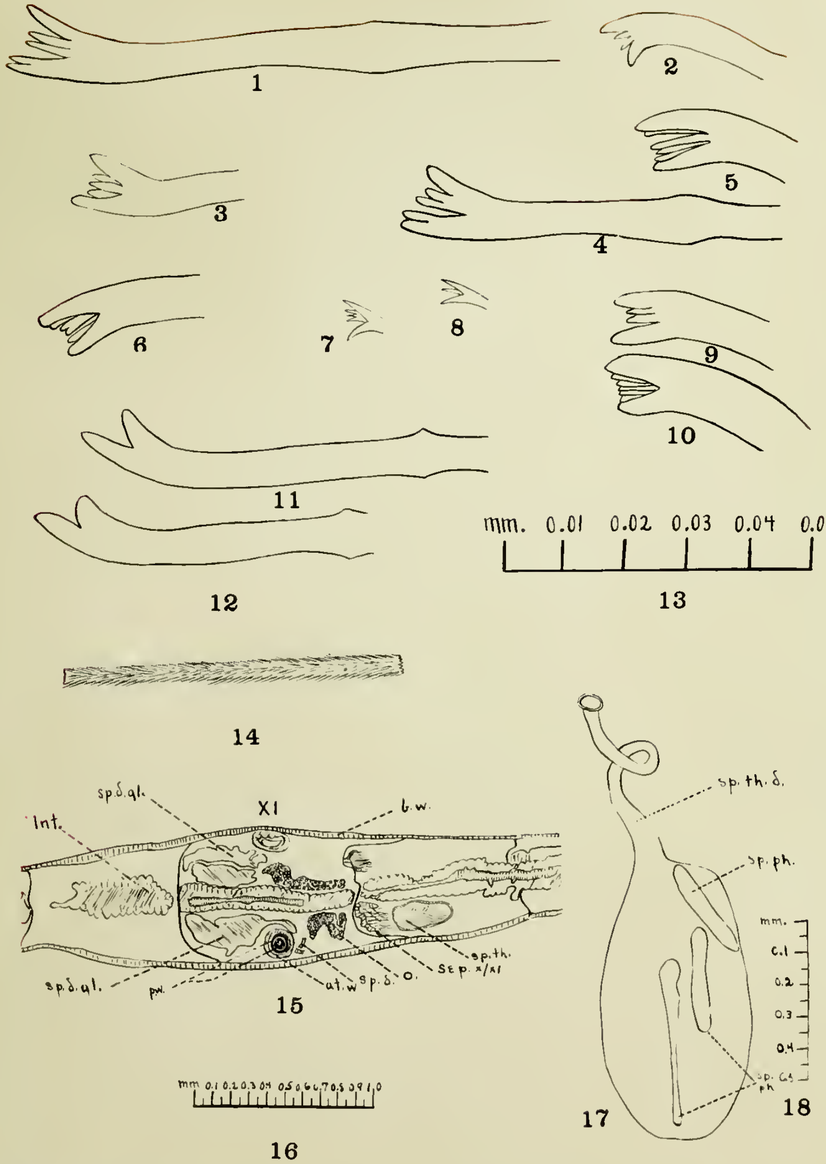
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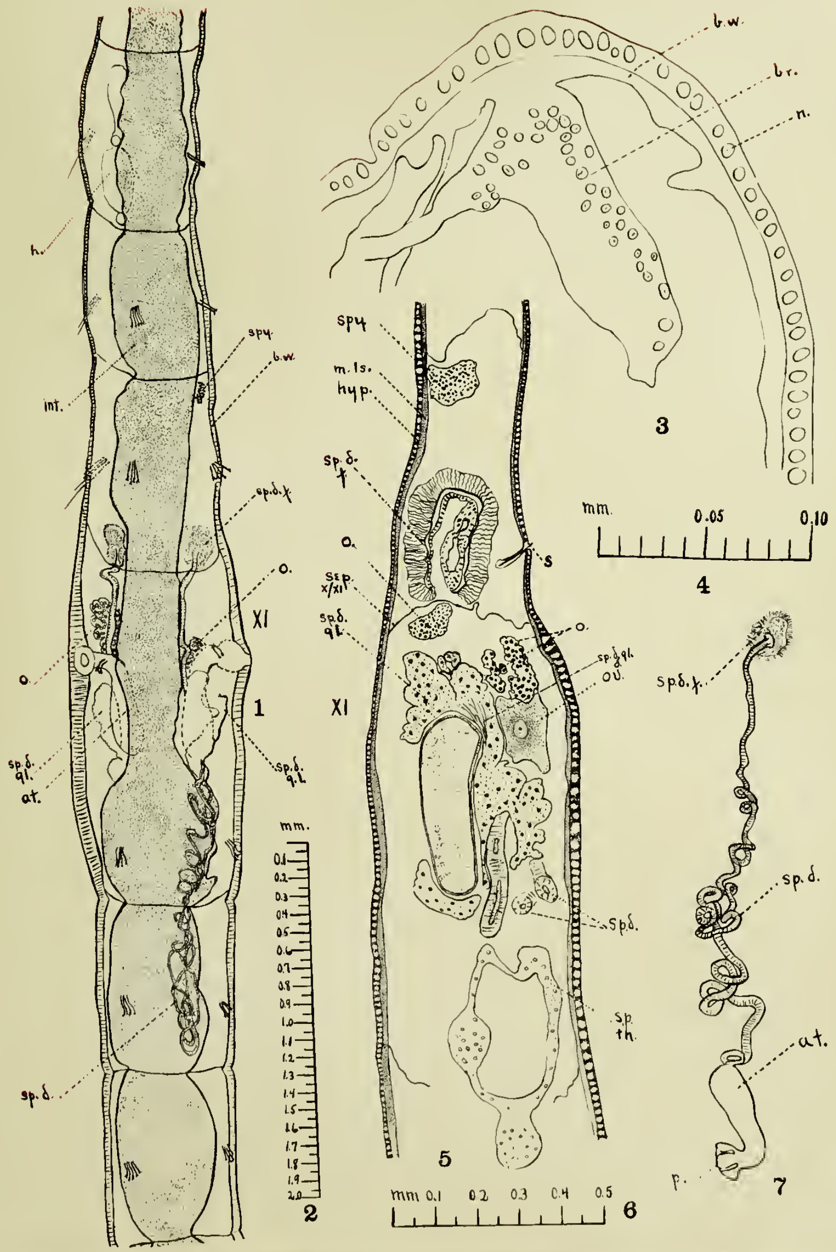
PLATE II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o.
XI
o.
1
sp.δ. gl.
at.
sp.δ. gl.
sp.δ.
mm.
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2
b.w.
br.
n.
3
mm.
0.05
0.10
4
spy
m.ls.
hyp.
sp.δ.f.
o.
sep. x/xi
sp.δ. gl.
XI
s
o.
sp.δ.gl.
ov.
sp.δ.
sp. th.
5
mm 0.1
0.2
0.3
0.4
0.5
6
sp.δ.f.
sp.d.
at.
p.
7